Measurements of the double spin asymmetry in inclusive jet production in polarized p+p collisions at sqrt(s)= 200 GeV

Joanna Kiryluk (MIT)
for the STAR Collaboration

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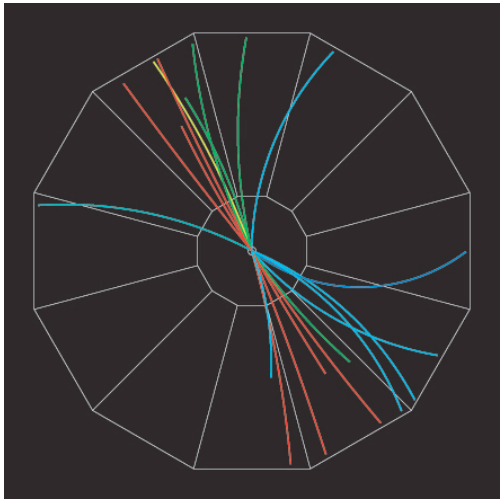
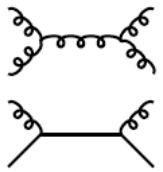
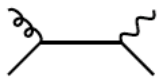


Outline:

1. Introduction – *ΔG from proton-proton interactions*
2. STAR Detector at RHIC
3. Data Selection
4. A_{LL} - (first) Preliminary Results
5. Systematics
6. Summary and Outlook

Determination of gluon polarization - a major emphasis at STAR-Spin program at RHIC

Inclusive production

Reaction	Dom. partonic process	probes	LO Feynman diagram
$\vec{p}\vec{p} \to \pi + X$	$\vec{g}\vec{g} \to gg$ $\vec{q}\vec{g} \to qg$	Δg	
$\vec{p}\vec{p} \to \mathrm{jet(s)} + X$ this talk	$\vec{g}\vec{g} \to gg$ $\vec{q}\vec{g} \to qg$	Δg	(as above)
$\vec{p}\vec{p} \to \gamma + X$ $\vec{p}\vec{p} \to \gamma + \mathrm{jet} + X$ $\sqrt{s}$ = 200(500) GeV	$\vec{q}\vec{g} \to \gamma q$ $\vec{q}\vec{g} \to \gamma q$	Δg Δg	

High production rate (low luminosity)

Classic 'tool' to access gluon distribution function - 'rare probes' (high luminosity)

Known NLO corrections (all cases)

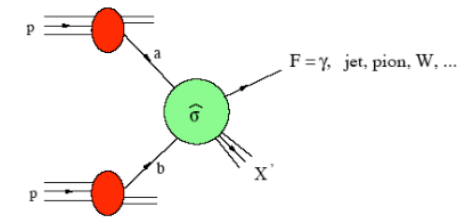
How are we going to access information about polarized gluon distribution function?

Inclusive jet production in pp interactions

- Cross section

$$(\Delta)\sigma \propto \sum_{\text{ab - sub-processes}} (\Delta)\text{pdf} \otimes (\Delta)\text{pdf} \otimes (\Delta)\hat{\sigma}_{ab} \quad \text{hard scattering}$$

$$p_T^3 \frac{d\sigma}{dp_T d\eta} = \left| \quad \right|^2 + \mathcal{O}\left(\frac{\lambda}{p_T}\right)^n$$

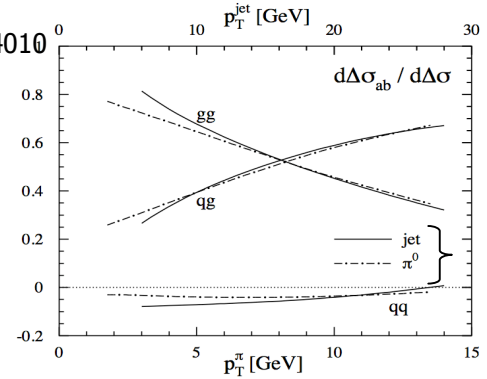


jets - no fragmentation functions are needed (systematics!)

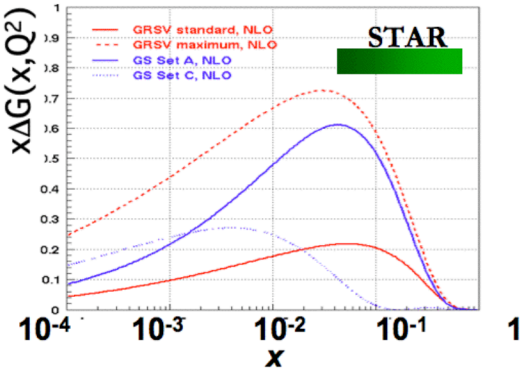
- Asymmetries $A_{LL} = \frac{\Delta\sigma}{\bar{\sigma}} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$

$\Delta\sigma$ - very small (difficult to measure), measure asymmetries instead, where most of systematic effects cancel out

Jager et.al, PRD70(2004)034010



similar

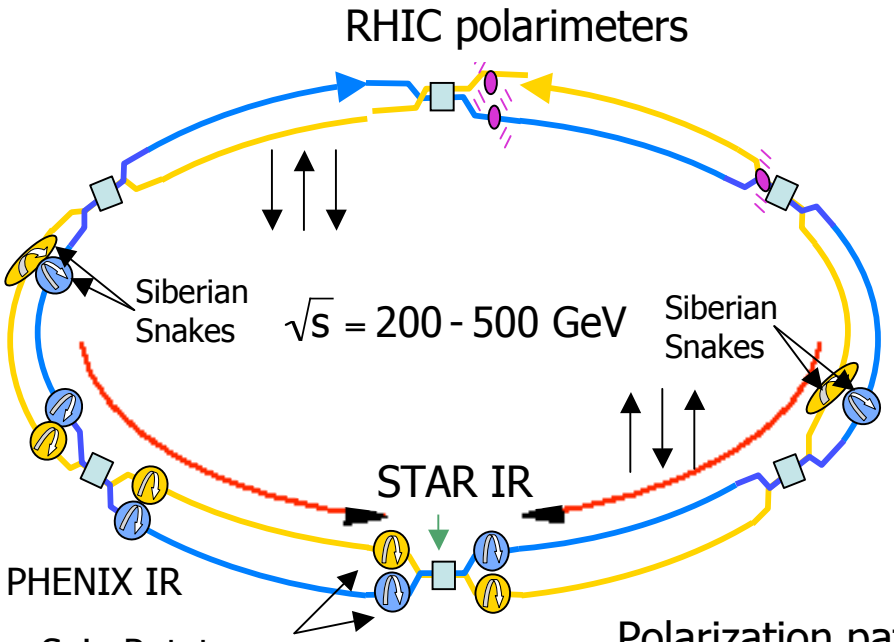


Sensitivity to the gluon polarization (no parton kinematics reconstruction)

- Convolutions "pdf × pdf × hard scattering" complicated and inversion $A_{LL} \rightarrow \Delta g$ not straightforward
- At the moment emphasis is on NLO predictions of A_{LL} in terms of "model" Δg
- Future: CTEQ-style global analysis of variety of A_{LL} data

W.Vogelsang

RHIC (*Relativistic Heavy Ion Collider*) - polarized pp collider

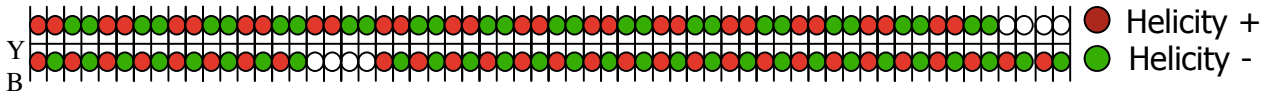


- two siberian snakes in each ring:
  stable polarization direction at RHIC - vertical beam polarization measured by RHIC polarimeters

- a pair of spin rotators in each ring around STAR (and PHENIX) IR (Interaction Region):
  longitudinal polarization at two Irs

STAR local polarimeter - to monitor beam polarization direction

Polarization pattern at STAR, e.g. in 2004

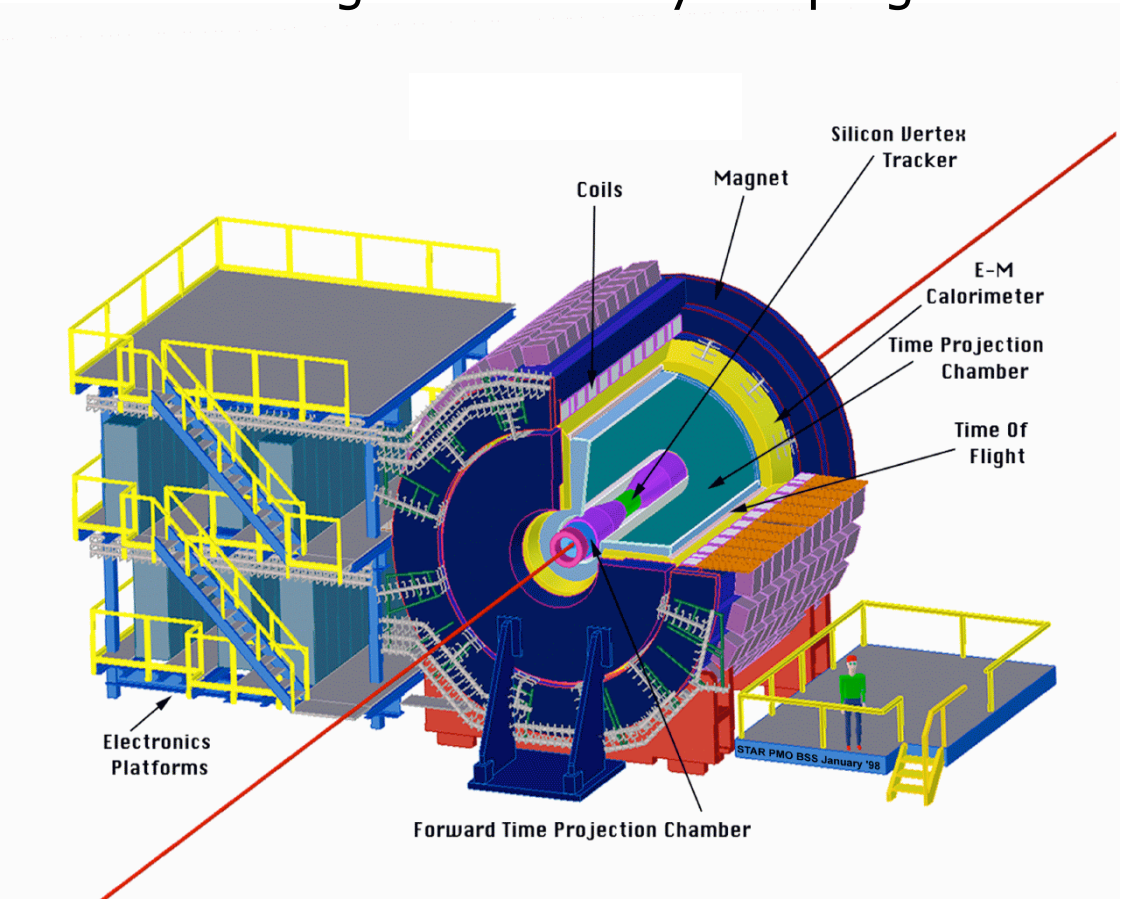


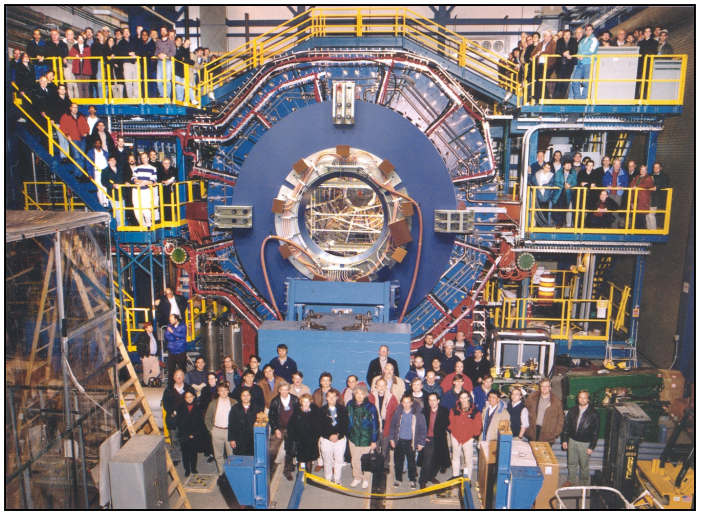
pp Run	2002	2003	2004	2005 - production	> 2006 LongTermGoals	
CM Energy	200 GeV				200 GeV	500 GeV
Beam polarization/direction at STAR	0.15 T	0.30 T/L	0.40 L	0.45 L/T	0.7 T/L	0.7 T/L
L_{max} [10^{30} $s^{-1}cm^{-2}$]	2	6	6	16	80	200
L_{int} [pb^{-1}] (STAR,delivered)	0.3	0.5/0.4	0.4	9 /0.4	320	800

Results from this data analysis presented in this talk

STAR Detector

- designed for Heavy Ion program to search for quark-gluon plasma





542 collaborators from
51 institutions and 12 countries

STAR detector

Solenoidal Magnet

- B = 0.5 T

Tracking Detectors

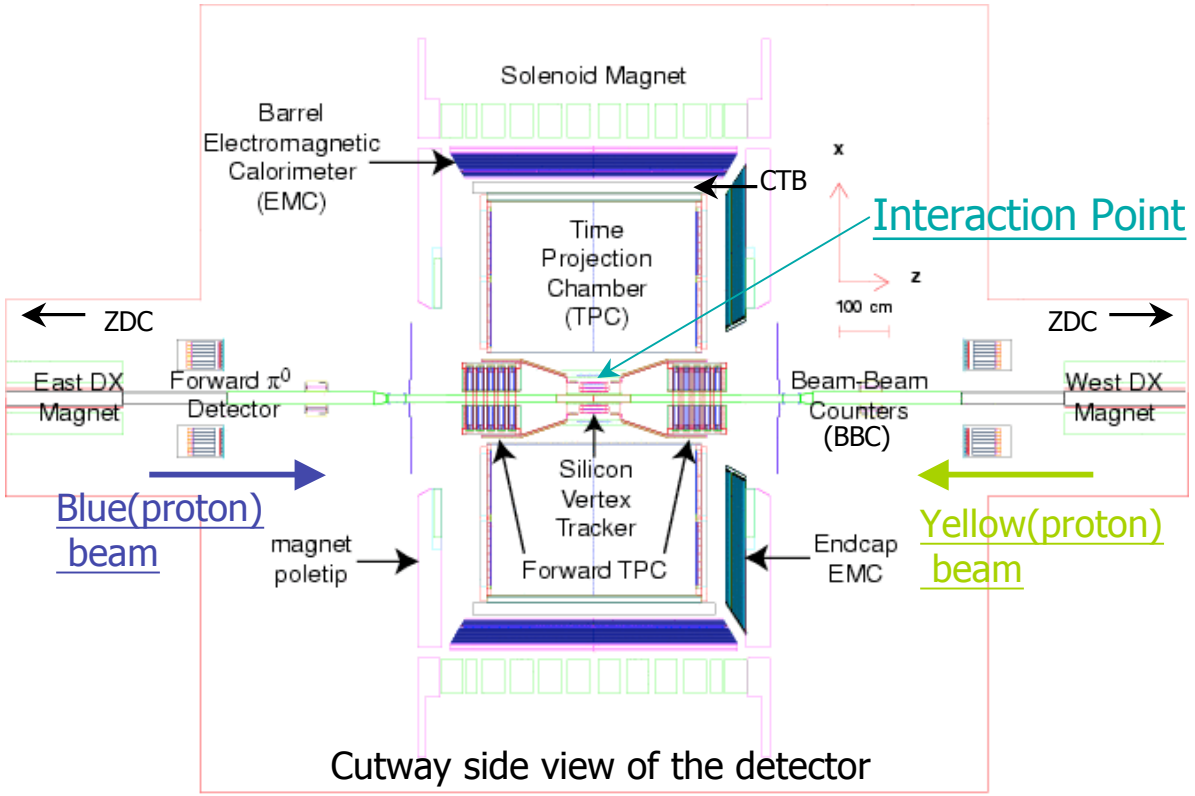
- Time Projection Chamber $|\eta|<1.6$
- Forward TPC $2.5<|\eta|<4.0$
- Silicon Vertex Tracker $|\eta|<1$

Trigger Detectors

- Beam-Beam Counters $3.4<|\eta|<5$
- Zero-Degree Calorimeter $|\eta|\sim6$

+ E-M Calorimeters - installation in stages (completed before 2006)

- Barrel EMC $|\eta|<1$
- Endcap EMC $1.0< \eta <2.0$
- Forward Pion Detector $3.3<|\eta|<4.1$



Cutway side view of the detector

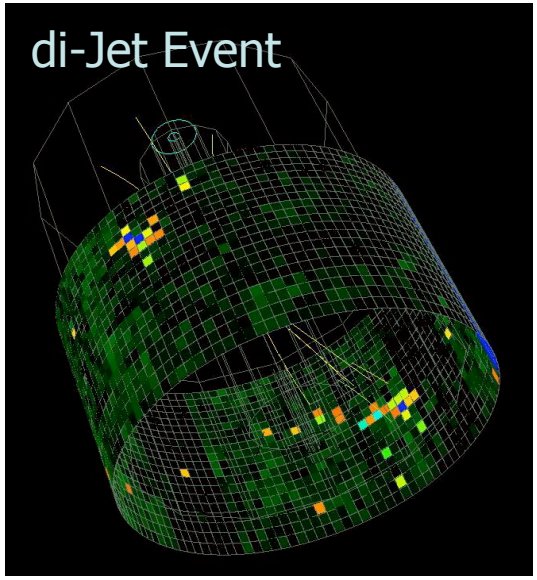
where pseudorapidity $\eta=-\ln \tan\theta/2$

TPC+EMC for jet reconstruction

BBC + scaler board system for (relative) luminosity and polarization monitoring
(information recorded every bunch crossing, i.e. 107 ns)

Jet reconstruction at STAR

Jet reconstruction at STAR - via TPC p_T for charged hadrons and EMC E_T for electro-magnetic showers



1) Jets reconstruction - cone algorithm (Tevatron)
seed energy = 0.5 GeV, cone angle R = 0.4 in $\eta-\phi$
splitting/merging fraction f=0.5

2) Trigger used in this analysis - High Tower:
E_T > 2.4 GeV deposited in one tower $(\Delta\eta \times \Delta\phi) = (0.05 \times 0.05)$
+ additional requirement of BBC coincidence.

3) Data set: ~0.3 pb^{-1} (2003 and 2004) recorded luminosity
$<P_b>$ =0.3 (2003) and $<P_b>$ = 0.4 (2004)

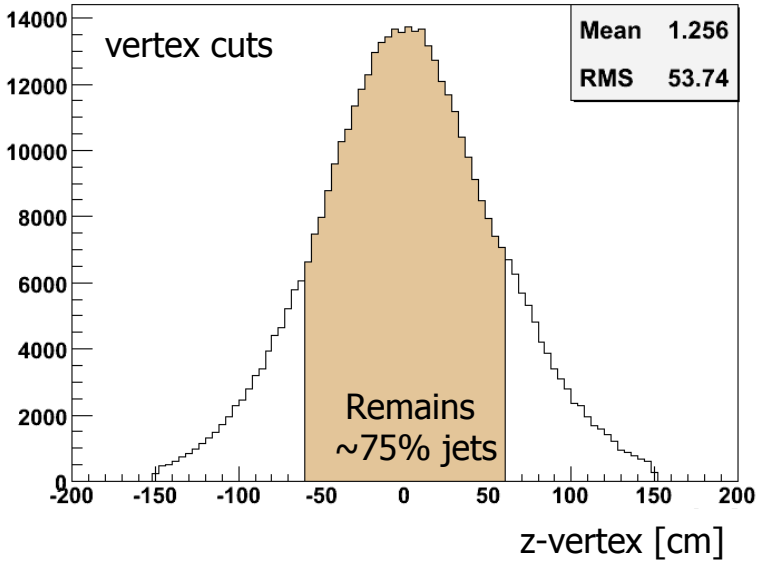
4) Cuts on:
- |z-vertex| < 75cm (2003) and < 60cm (2004)
- charged tracks $|\eta|$ < 1.6 and p_T >0.1 GeV/c
- jets: p_T jet > 5 GeV/c , 0.2< jet η (det) <0.8
- background: E_{EMC}/E_{tot}< 0.9 (2004) and < 0.8 (2003)

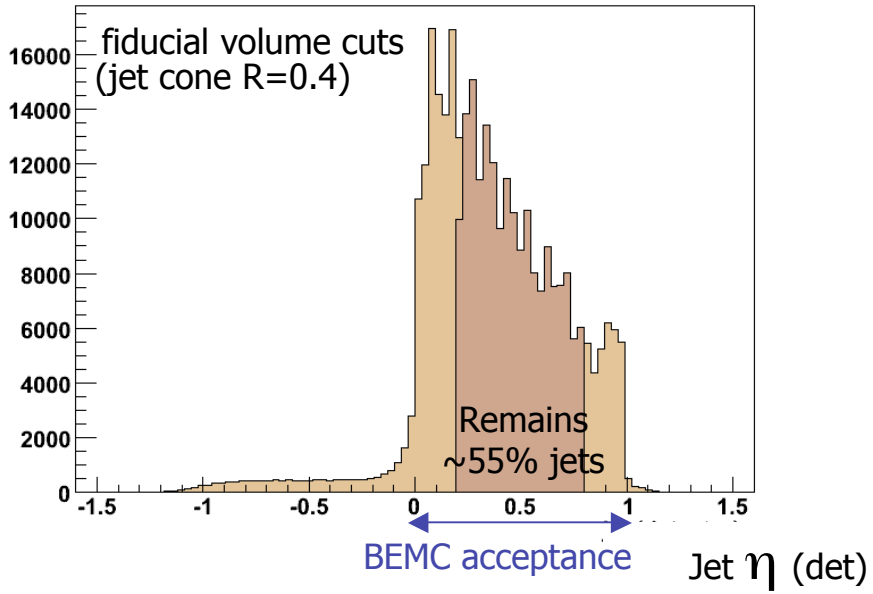
Inclusive jet cross section measured over (large!) range 5 < jet p_T< 50 GeV/c.
-talk by M.Miller, MIT- Session II.5 Thursday

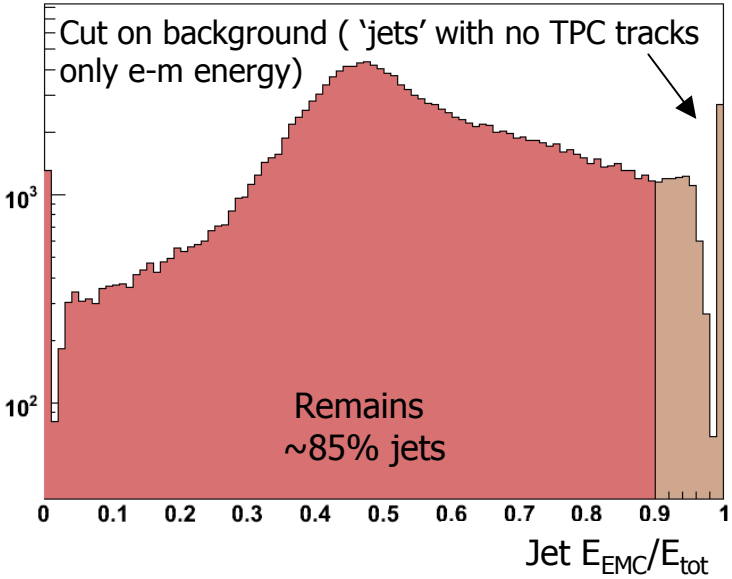
5) Final statistics (after cuts) for 5 < jet p_T < 17 GeV/c:
125k (2003) and 162k (2004) = 300 k jets

Effect of cuts on jet statistics (e.g. 2004)

Initial sample = 1.4 M HighTower trigger events (0.4 M jets reconstructed)







Number of jets (HighTower events)
about ~35% jet survives these cuts
- 160k final (2004) statistics

Double Longitudinal Spin Asymmetry Measurements

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P_1 P_2} \times \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}$$

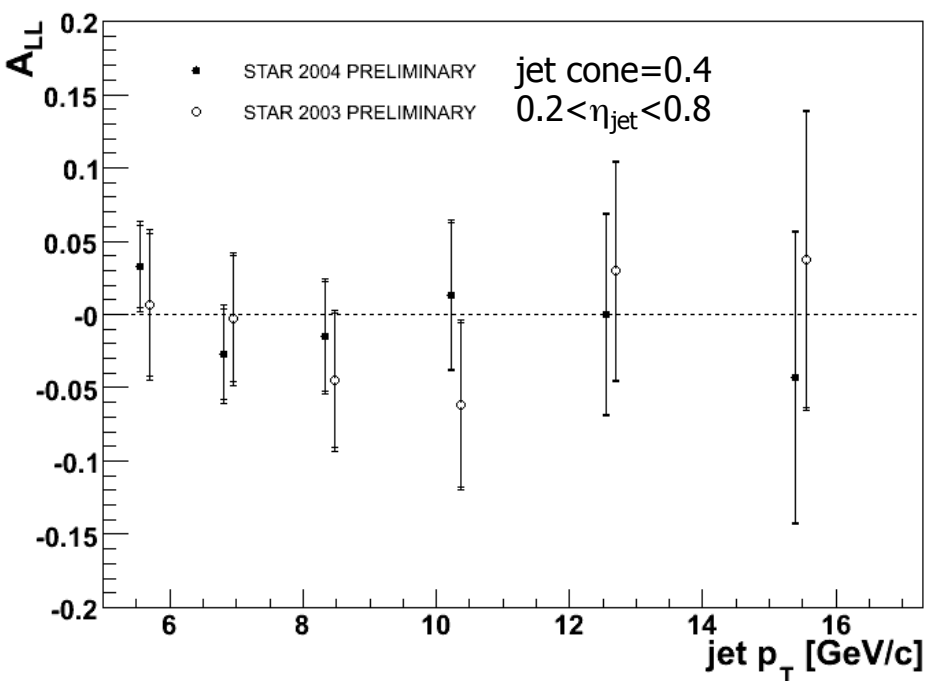
Statistical significance: $P_1^2 P_2^2 \cdot \int \mathcal{L} dt$

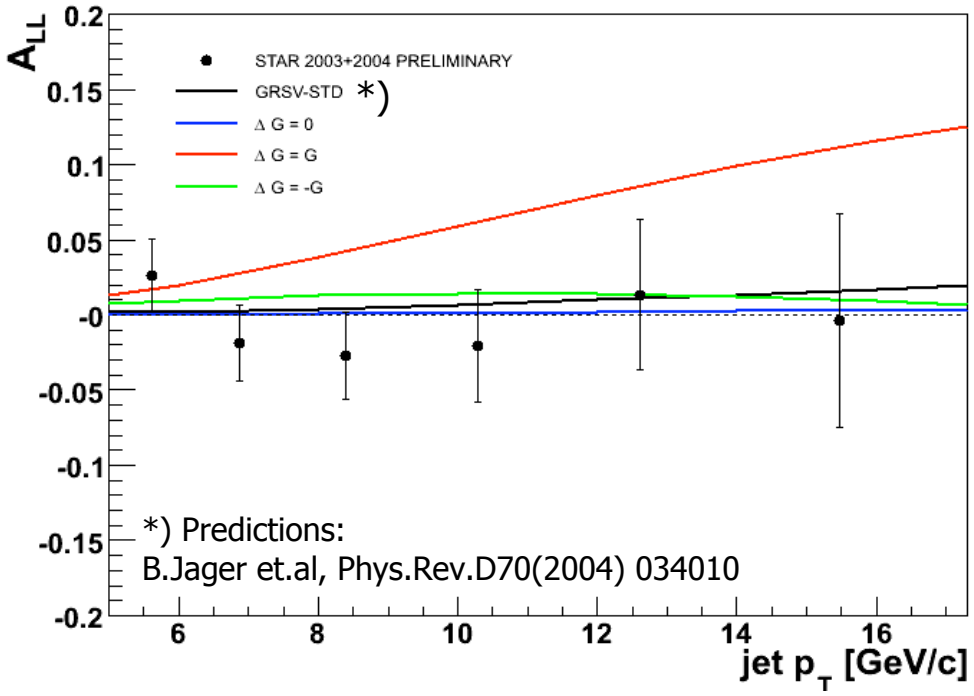
Require concurrent measurements:

- magnitude of beam polarization, $P_{1(2)}$ → RHIC polarimeters
- direction of polarization vector at interaction point } BBC + scalers
- relative luminosity of bunch crossings with different spin directions: $R = \frac{L_{++}}{L_{+-}}$ } BBC + scalers
- spin dependent yields of process of interest N_{ij}

} STAR experiment

Double spin asymmetry A_{LL}(preliminary) results in inclusive jet production in p+p collisions at sqrt(s)=200GeV





- Consistent results from 2003 and 2004 analyses
- Results limited by statistical precision
- Total systematic uncertainty ~0.01 (STAR) + beam polarization (RHIC)

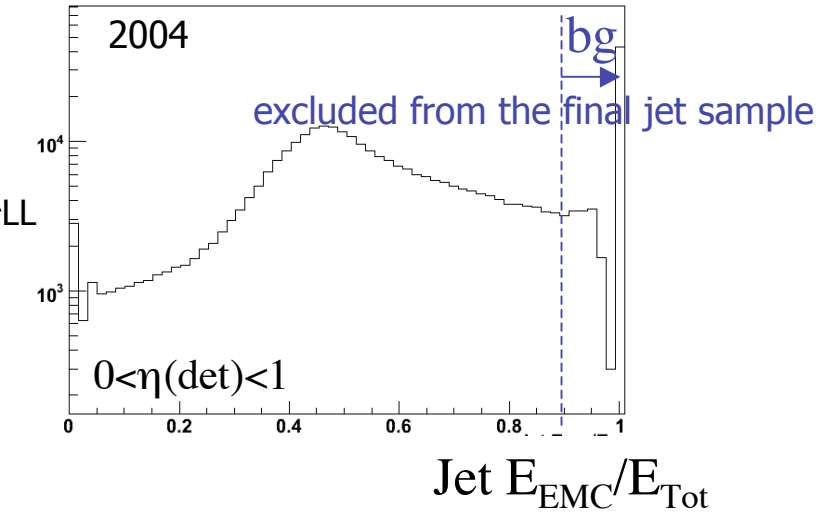
  Sources of systematic uncertainties: background contribution, trigger bias, relative luminosity, residual (non-longitudinal) asymmetries, bunch to bunch systematic variations (random pattern analysis) + beam polarization

A_{LL} systematics - a closer look

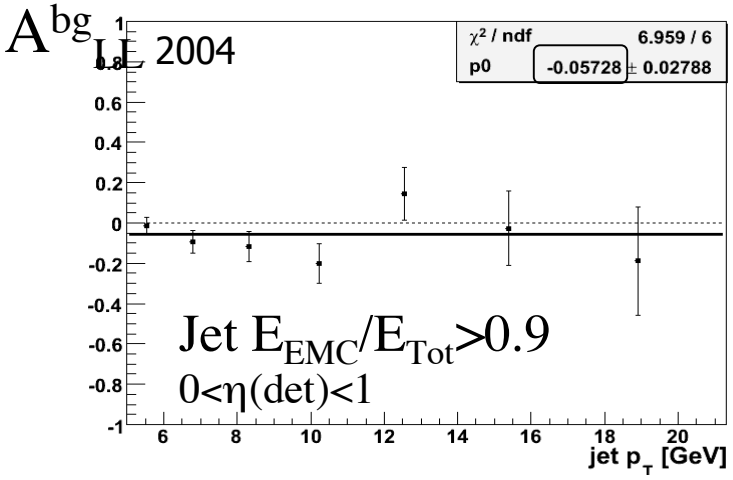
- Jet background contribution
  (= 'jets' with no TPC tracks, only e-m energy)

- can cause a bias in the measurement of A_{LL}

$$A_{LL}^{meas}(p_T) = \frac{A_{LL}(p_T) + f_{bg}(p_T) \times A_{LL}^{bg}(p_T)}{1 + f_{bg}(p_T)}$$



We estimated (i) the background spectrum and background fraction f_{bg} in the final (after all cuts, including Jet E_{EMC}/E_{tot} <0.9 cut) jet sample and (ii) extracted background asymmetry A^{bg}_{LL}



f_{bg}<0.05

A^{bg}_{LL} ~ -0.06 ± 0.03

$\delta_{sys,bg} A_{LL} < 0.003$

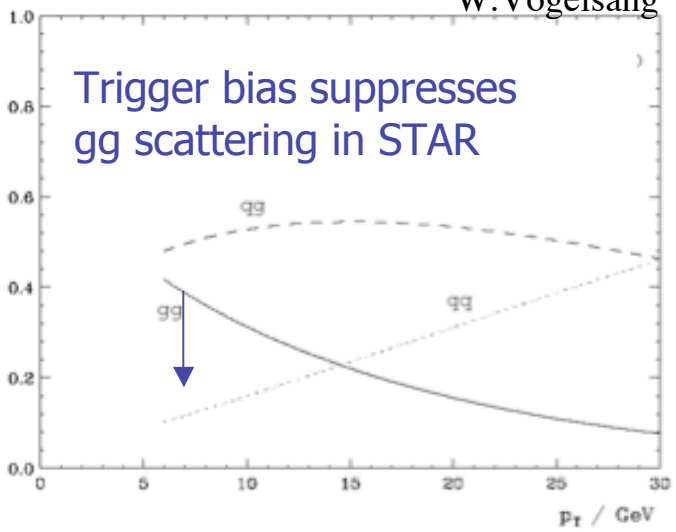
A_{LL} systematics - a closer look

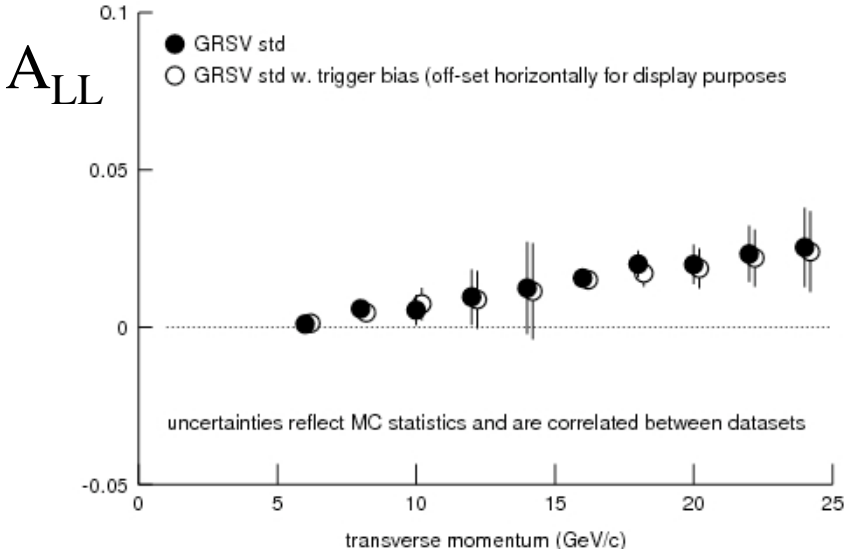
- Trigger bias

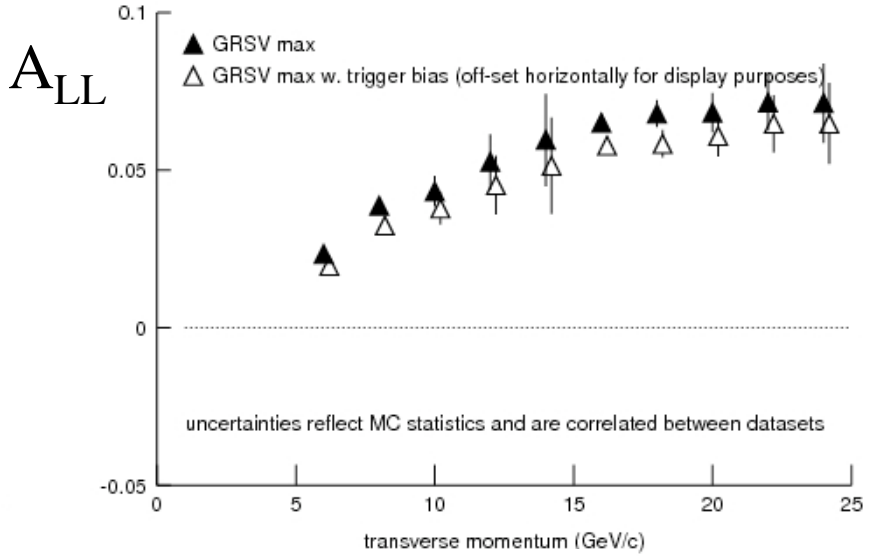
W.Vogelsang

High Tower trigger *($E_T > 2.4$ GeV deposited in one tower)* selects on e-m energy deposits and may thus distort the partonic sub-process contributions in inclusive jet production.

Possible size of this effect was estimated from MonteCarlo (Pythia+GEANT) simulations of the trigger response, and from various polarized parton distribution functions such as GRSV-std and -max.



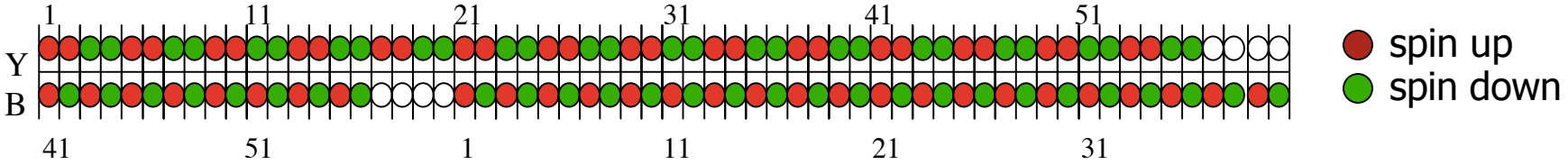




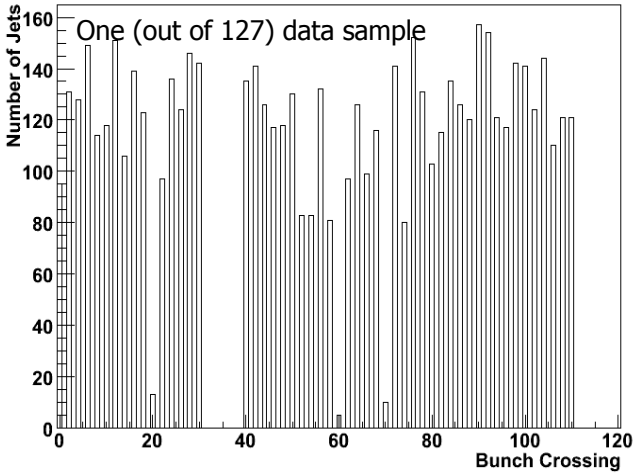
$$|A_{LL}(\text{with bias}) - A_{LL}(\text{no bias})| < 0.007$$

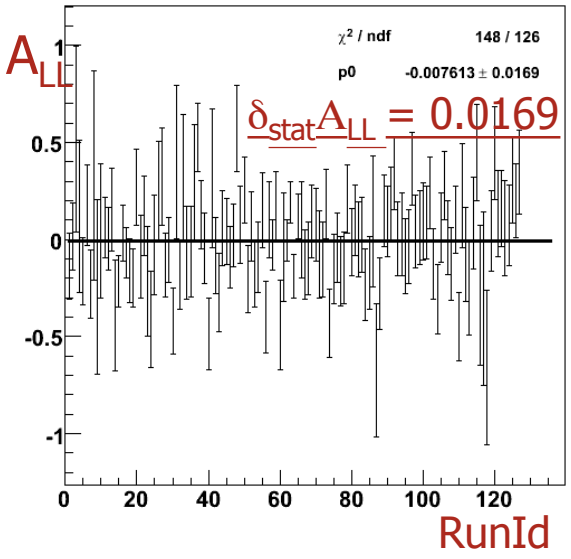
Systematic Study for A_{LL} - Random Fill Pattern Analysis

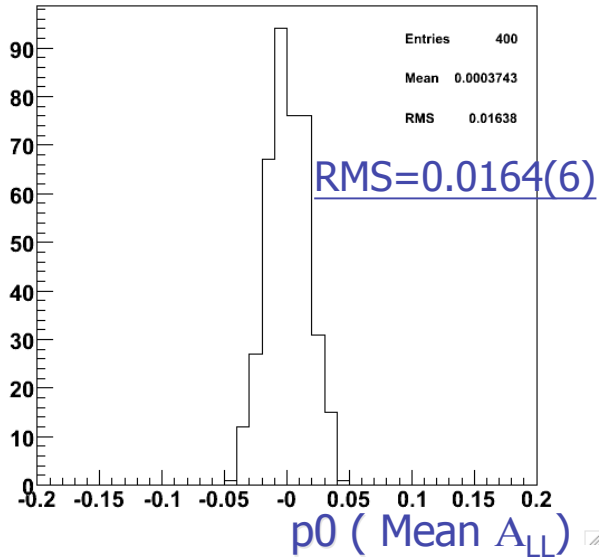
- Method: take true fill pattern (56 bunches in 2004) and mix assignment of spin up and down bunches (red and green points) to the bunch crossing number



- Input
- Result for: one random fill pattern and 400 random fill patterns

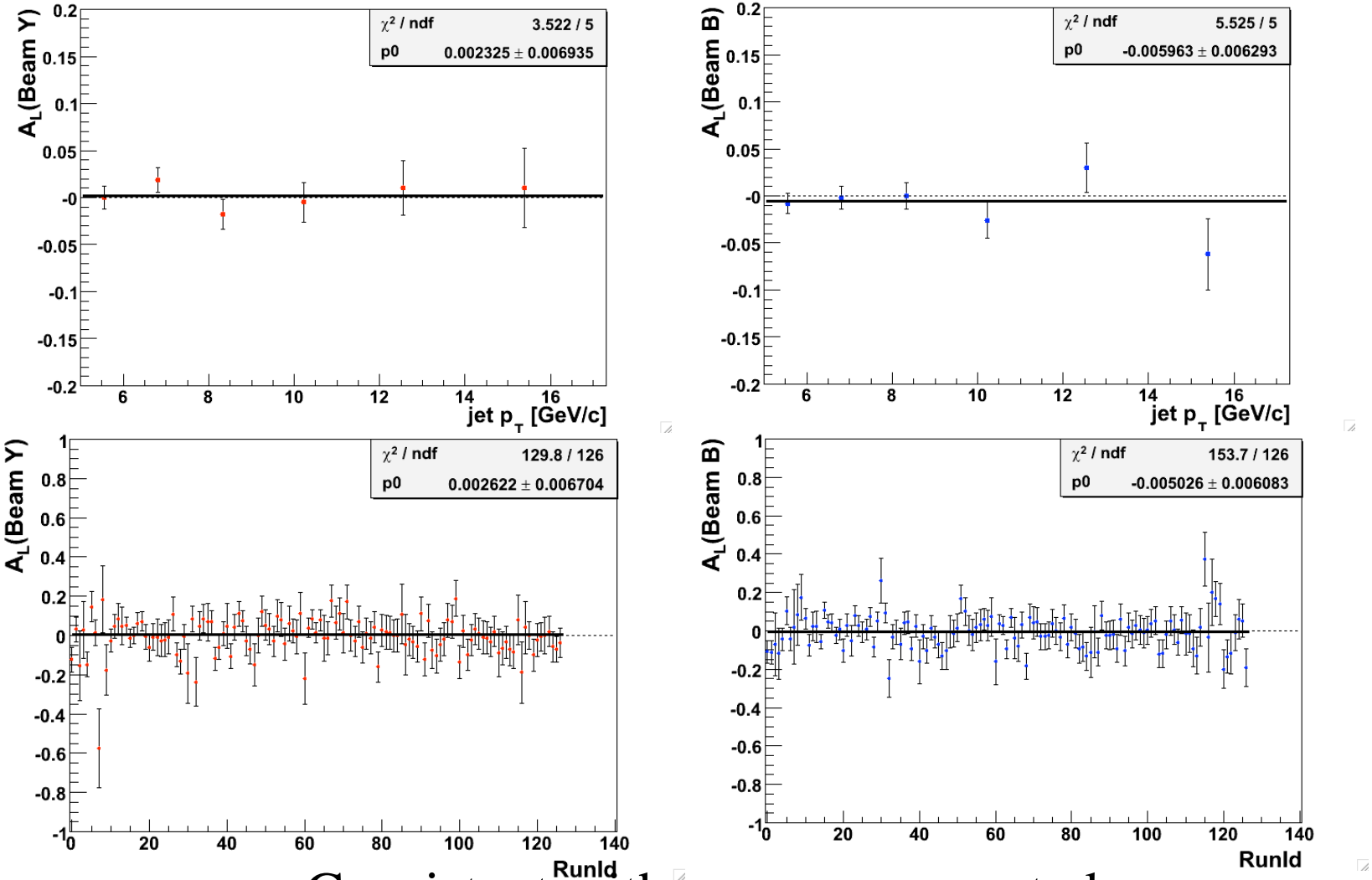






The RMS is consistent with A_{LL} statistical uncertainties indicating that bunch to bunch and fill to fill systematic uncertainties are negligible

Cross checks - e.g. (2004) parity violating asymmetries



Consistent with zero - as expected

All other asymmetries were found consistent with zero

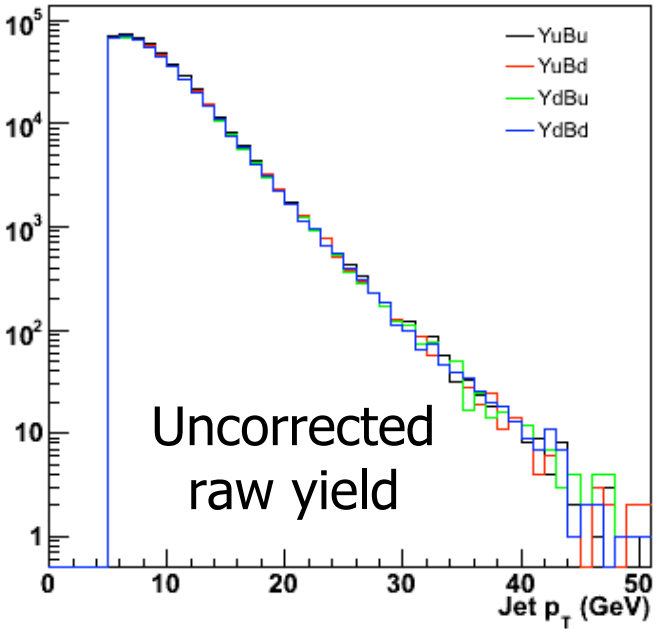
Status of Run5 data analysis

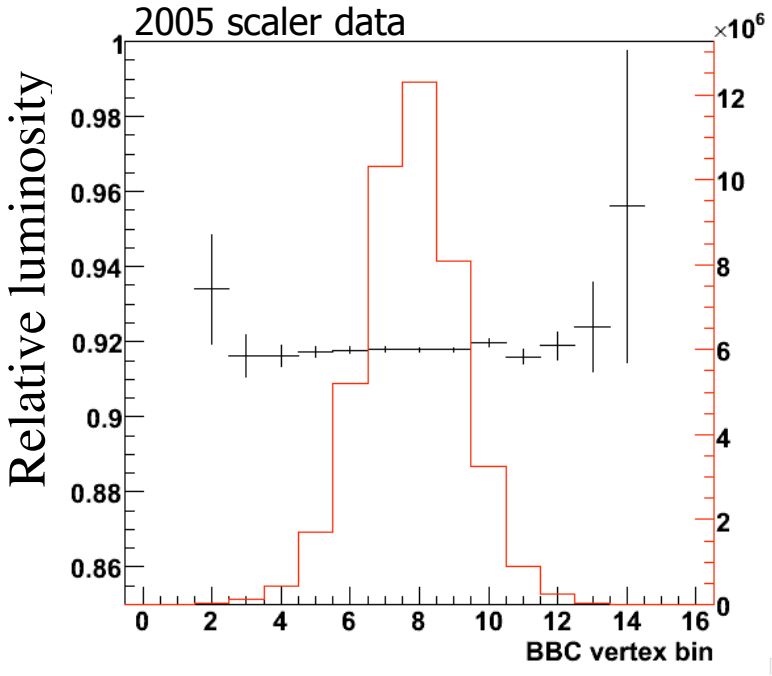
Improvements for Run5 (Spring 2005)

- P_b~45% (~40% in Run4) L= 3/pb (0.3/pb in Run4)
  FoM (Run5)/FoM(Run4) = 16
- Acceptance: 3/4 BEMC complete (1/2 in Run4)
- BEMC Jet-Patch ($\Delta\eta$ x $\Delta\phi$ =1x1) trigger data collected in addition to High-Tower trigger data.

Jet sample:
- HT trigger ~0.7M (0.16M in Run4)
- JP trigger ~2.2M (test in Run4)

BEMC Jet-Patch trigger

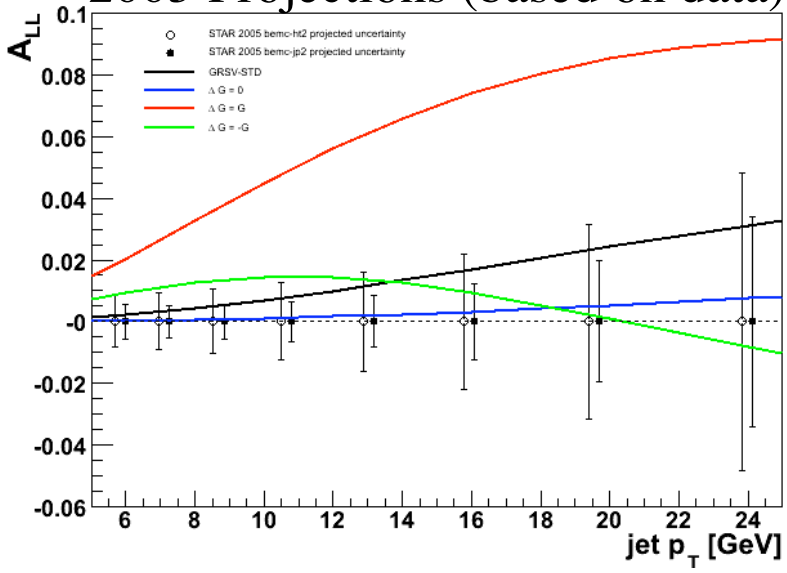




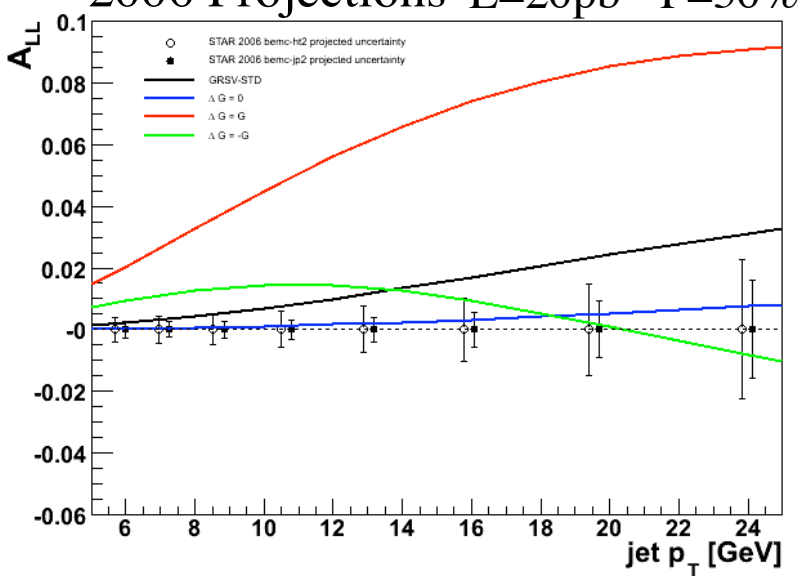
- The analysis of the more precise Run5 data is well under way.
- We are studying systematic effects, such as spin dependent backgrounds to correspondingly refined levels of accuracy.
- For Run5 the relative luminosities are resolved in vertex-z (additional scaler boards)

Inclusive jet production - prospects for Run5 (first long pp run) and Run6 (requested)

2005 Projections (based on data)



2006 Projections $L=20pb^{-1}$ $P=50\%$



STAR requests a long pp run in Run6 which should give a FoM improvement by >10 over Run5.

STAR will be able to distinguish between various scenarios for gluon polarization in the proton.

Summary and Outlook

- We presented the first (preliminary) results for the measurement of double spin asymmetry A_{LL} in inclusive jet production in polarized proton-proton collisions at sqrt(s)= 200 GeV over the measured jet p_T range 5-17 GeV .
- The data was collected during 2 weeks in 2003 (first physics pp run at RHIC with longitudinally polarized beams) and 2 weeks in 2004 (commissioning run) with average beam polarizations of about 30% in 2003 and 40% in 2004.
- The asymmetry A_{LL} is consistent with evaluations based on DIS over the measured kinematic range of jet $5 < p_T < 17$ GeV/c.
- The results for A_{LL} are limited by statistical uncertainties of about 0.015 and currently do not distinguish between the different scenarios for gluon polarization in the proton allowed by polarized DIS data.

Prospects for Run5 and Run6

- In Run5 STAR collected ~10 times more statistics (the first long pp run) with higher beam polarization (better source) than in 2003 and 2004.
- STAR will be able to distinguish between various scenarios for gluon polarization in the proton.